Energy Policy Toolkit on

Energy Efficiency in New Buildings

Experiences from Denmark

DANISH ENERGY AGENCY

The toolkits are drafted by the Danish Energy Agency (DEA) under the Danish Ministry of Climate, Energy and Building. DEA will publish a series of toolkits providing specific, technical and concrete information on Danish experiences and lessons learned on tools and measures in promoting renewable energy and energy efficiency, targeting practitioners, governmental energy experts and policy makers in growth economies and developing countries. The aim is to give qualified guidance to countries in their implementation of Green House Gas (GHG) reduction measures and Low Emission Development Strategies (LEDS).

Comments to this policy toolkit as well as queries on the Danish Energy Agency's Global Assistance are most welcome. The idea is to further refine recommendations according to identified needs in growth economies and developing countries. For comments and queries please contact: Mr. Kristian Havskov Sørensen, Chief Advisor, e-mail: khs@ens.dk, phone +45 3392 6738. For more information on DEA's Global Assistance and its policy toolkits please visit www.ens.dk/en/Global-assistance

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Introduction

Countries around the world face critical energy choices. The goal of economic growth and future prosperity is challenged by energy needs and international efforts to find solutions to mitigate global warming. Thus the energy choices revolve around choosing appropriate policies and measures, on decisions with regard to the energy mix and on the timing and scope of investments in energy infrastructure. A key question for energy planners remains whether today's investments in energy infrastructure should be based on traditional fossil fuels or on energy efficiency and savings and renewable energy technologies?

The traditional fossil fuel oriented approach may still be cost-efficient in the shorter run compared to some of the more costly renewable energy sources but is clearly unsustainable in the longer run. The alternative and sustainable approach is that of energy savings and promotion of energy efficiency and renewables. While fossil fuel prices are expected to rise further, the cost of renewable energy technologies may very well fall due to maturing of the technologies and an increase in demand with associated economics of scale. Thus the necessity of transferring the energy systems from reliance on fossil fuels towards renewable energy sources does not necessarily run counter to future economic prosperity.

This energy policy toolkit shares knowledge and experiences gained in the Danish case on handling barriers and improving energy efficiency of new[1] buildings.

1. This toolkit specifically addresses energy efficiency in new buildings. Measures targeting the existing building stock will be dealt with in another Danish Energy Policy Toolkit.

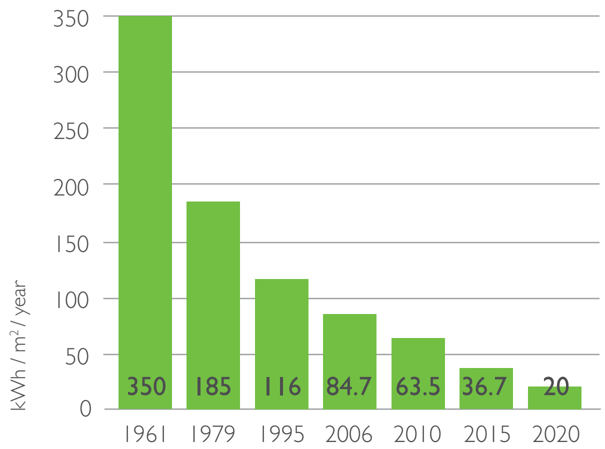


Figure 1. Danish building codes from 1961 to present: Maximum allowed energy demand per year and m2 heated floor space in a new 150 m² residential building. The limit is on the total amount of supplied energy for heating, ventilation, cooling and domestic hot water.

Poor energy performance significantly increases the operating costs of a building. To a large extent, this can be avoided through simple design measures, which are easily paid for by the saved energy costs. However, many new buildings are designed and built with no regard for this, resulting in a significant waste of energy and money.

Evidently, different barriers, such as split incentives[2] or short-term investment horizons, stand in the way of profitable energy efficiency decisions. Therefore, a better understanding of these barriers, and how to deal with them, is the key to a huge economic potential.

Generally speaking, the cost/benefit ratio of an energy efficiency measure is most attractive in new construction. For example, providing a building which is under construction with energy efficient glazing or air conditioning may be quite a lot cheaper than retrofitting the same components in an existing building. In other words, insufficient energy efficiency in new construction is a missed opportunity, which may lock consumption in at a high level and prove very costly in the long run. This is true everywhere, but it is particularly acute in countries with a rapidly growing building stock.

Not only does energy efficiency save energy costs. It may also make costly power failures less likely and reduce the need for huge investments in power plants and transmission lines.

Why buildings matter:

- Buildings account for a large share of total energy consumption. In many developed countries this share is around 35-40% which is more than any other sector.
- Existing technology has been providing a huge savings potential and continues to do so. For example, buildings that are net suppliers rather than consumers of energy already exist. In virtually no other sector does off-the-shelf technology offer the possibility of such a significant change.
- Many buildings have a long lifetime. Poor energy efficiency in a building that will stand for many years locks consumption in at a needlessly high level – the lock-in occurs, because retrofitting is much costlier than getting it right at the time of construction.
- Energy efficiency in buildings shares important traits with construction in general: It is labour intensive and tends to generate local employment and know-how.
- Many energy efficiency measures in buildings are cost-effective, in particular when long term costs are considered. Not only do such measures save energy costs, they may also make costly power failures less likely and render huge investments in extra generation capacity superfluous.

2. I.e. when the investor is not the one benefitting from savings on the energy bill.

Regulation

For policy makers there are several instruments, which may help achieve energy efficiency objectives. But regulation – most often in the form of mandatory performance requirements in the building code – stands out as the key instrument which can reliably turn potential into actual energy savings.

- Properly implemented regulation ensures that minimum energy performance standards are met in all buildings concerned by the regulation. Builders may decide how to comply in the most cost effective way, but they cannot opt out or ignore the issue.
- Regulation may overcome "market failures", "split incentives" and other obstacles to the implementation of cost effective energy savings. In particular, regulation may be designed to target long term cost efficiency, something which may be nearly impossible to achieve with other policy instruments.
- Regulation is essential also because it provides an environment which encourages innovation in energy efficiency.

Of course, regulation is much less effective – even useless – if it is not properly implemented. So design and implementation of regulation are equally important.

Also, regulation will be more effective if it is supported by financial incentives and if the underlying purpose is generally understood and accepted. This will be dealt with in subsequent chapters.

Design of energy efficiency requirements

The design of energy efficiency requirements must take a number of country- or region-specific factors into account. These include the type of climate, the cost of energy use, current construction practices, know-how with local architects, engineers and construction companies, the cost and availability of energy efficient technologies, and – last but not least – local authorities' capacity for enforcement.

However, experience with some of the general aspects in energy efficiency regulation may be shared across climate zones and different economic environments.

The following are some of the key elements, which have proved successful on the Danish path towards energy performance standards, which are widely regarded as the best in the world.

Building envelope requirements

In Denmark, as in many other countries, the first requirements were about thermal insulation of the building envelope, i.e. roof, outer walls, slab on ground (in colder climates), windows and doors. They were introduced in the 1961 building code, and the level of requirements was quite low compared to present standards. For example, 80 millimeters of mineral wool were enough to comply with requirements on roof insulation, where 400 mm is a typical figure by today's standards.

Although quite modest, the requirements prevented a huge waste of energy from new buildings, which became much cheaper to operate and also healthier and more pleasant to live in. Therefore, the requirements were highly cost-effective.

In cold climates, like the Danish, insufficient thermal insulation means that energy provided for space heating is wasted. But thermal insulation may be equally important in warmer climate zones, where cooling is a common feature in new buildings. Here, thermal insulation will reduce power demand, in particular on hot days when supply is most strained. And since generation of one extra unit of electricity may require several units of primary energy[3], such reductions in peak power demand are particularly important.

Apart from being cost effective, simple requirements on thermal insulation may be attractive because implementation and verification of compliance are fairly straightforward, and because insulation materials can be produced locally.

Requirements may specify the level of thermal resistance for different parts of the building envelope and provide examples of construction details that are in compliance.

Power demand for cooling may be reduced also through other low cost measures, which should be considered in the design of requirements:

- Building geometry, shading, size and orientation of windows and glazing (which may significantly reduce solar heat gains at no or very low cost). For instance, in tropical areas near the equator, north and south facing windows are much to be preferred as they can easily be shaded to prevent direct sunshine from entering the building.

- Glazing area should be limited while still providing view, comfort and adequate daylight. Overglazed buildings in warm climates are very costly, not only in terms of energy consumption due to the cooling load but also because they require a bigger and more expensive cooling system.

Air-tightness of the building envelope is another quality, which impacts energy efficiency in hot as well as in cold climates (e.g. if outside air leaks into a building, energy demand for heating or cooling will increase significantly). Simple, low cost measures may significantly improve air-tightness and reduce energy demand. In particular, leaks tend to be with doors, windows and connections between different building components.

3. Transmission and conversion losses, in particular conversion losses at thermal power plants, mean that 1 kWh of electricity consumed in a building may require 2-3 kWhs or more of primary energy for its generation.

Requirements on installations for heating, cooling, ventilation, lighting and sanitary hot water

Requirements on the building envelope may provide the largest and easiest-to-achieve savings. Also, such savings are particularly robust, because they do not depend on regular maintenance.

However, the potential of requirements on installations is also very significant. Large amounts of energy and money are wasted because the energy efficiency of lighting, cooling and other systems is neglected.

Requirements of this kind were introduced in the Danish building code for the first time in the late 1970s. Since then they have been revised regularly in order to phase out inefficient technologies and mandate the most efficient ones. At present, the requirements cover heating, ventilation, cooling and lighting.

Requirements should be designed to match local capacity for test and certification of equipment and for on-site verification of installations. In this respect, some requirements on installations may be more technically demanding than those concerned with the building envelope.

However, there are also a number of relatively simple measures, which may be included in the requirements, even if local, technical capacity is limited, e.g.:

- Maximum installed lighting load in non-domestic buildings (maximum W/m^2)
- Use of natural daylight (while avoiding glare and overheating)
- Solar heaters for hot sanitary water

The use of natural daylight to offset electric lighting has a huge energy saving potential, in particular in tropical and subtropical climates where daylight is available throughout daytime all year round. Annex A provides practical guides on how to exploit this, while avoiding glare and increased cooling loads.

Requirements on overall energy performance

In addition to specific requirements on the building envelope and on installations, many countries now have a requirement on the energy performance of the building as a whole.

In Denmark this was introduced as an option in 1995. By 2006 it became mandatory to provide a calculation of overall demand for primary energy in all new buildings. The calculation must follow specific guidelines and must include demands for heating, ventilation, cooling, domestic hot water and non-residential lighting. The Danish Building Research Institute[4] provides software, which may be used for the calculation. Users pay a small annual fee for the software.

The main advantage of an overall energy performance requirement is that it encourages building designs, which integrate the many aspects of energy efficiency in a cost effective way.

On the other hand, the calculation of a building's overall energy performance is a somewhat complex affair, which involves a large amount of input data. Collecting these and making sure they are valid requires a rather comprehensive set-up, even if the actual calculation is performed by standard computer software.

In Denmark, as in other countries which have a similar set-up, these capabilities have been developed over many years. In particular, test and certification laboratories have been providing reliable data on heating, cooling and ventilation systems, windows, insulation materials etc. This expertise was built up during the implementation of specific requirements regarding the building envelope and installations, i.e. well before the overall energy performance calculation became mandatory.

4. The Danish Building Research Institute is a national institution which develops research-based knowledge to improve buildings and the built environment. The institute is affiliated with Aalborg University, one of eight Danish universities. The institute identifies and communicates on subjects that are important for professionals and decision-makers in the building sector. www.sbi.dk/en.

KEY

Key points and recommendations from the Danish case

Buildings components:

- Simple building code requirements may provide highly cost-effective energy savings in new buildings.
- The list below gives examples of issues and building components, which may be covered by such requirements.
- Generally speaking, the first items on the list are the easiest to implement. Items further down the list may require a more comprehensive set-up in terms of test laboratories, certification schemes, training etc.

1. Shading, size and orientation of windows/glazing
2. Use of natural light (while avoiding glare and overheating)
3. Energy efficient electric lighting
4. Solar heaters for hot sanitary water
5. Thermal insulation of the building envelope
6. Air-tightness of the building envelope
7. Energy efficient cooling (in warm climates)
8. Energy efficient heating systems (in cold climates)
9. Energy efficient ventilation
10. Energy efficient pumps and fans.
11. Energy efficient appliances (IT equipment, fridges, freezers, washing machines etc)

Overall performance:

- Complement building component requirements with requirements on overall energy performance, but only when basic requirements on the building envelope and on installations are welldesigned, sufficiently demanding and implemented.

FACT

Factsheet

Danish Building Code requirements for new construction

Danish requirements apply to most new buildings, including single family houses.

Overall energy performance

For a residential building the maximum limit on energy demand per year is 1650 kWh/HFS plus 52.5 kWh/m^2, where HFS is the building's total heated floor space measured in square meters.

For a non-residential building the equivalent figures are 1650 kWh/HFS plus 71.3 kWh/m^2.

Demand must be calculated according to specific guidelines and must include energy supplied from external sources for heating, ventilation, cooling, domestic hot water and non-residential lighting. The guidelines include standard input data like average weather data which make it possible to take account of heat losses as well as solar heat gains. Demand for cooling (i.e. if the calculation shows that indoor temperature will go above 25^0 C without cooling) must be taken into account, even if the building is not planned to have a cooling system.

Energy from wind and solar on the site (e.g. solar thermal or photovoltaics) is offset against the demand for energy supplied from external sources.

Building envelope and installations

A new building must also comply with specific requirements regarding

- thermal resistance for each of the non-transparent elements in the building envelope (roof, walls, slab on ground, doors without glazing) and for typical thermal bridges (foundation, joints between walls and windows/doors)
- "energy gain" (solar gains minus heat losses) through a typical heating season for transparent parts of the building envelope (i.e. windows, glazed walls etc.)
- overall thermal resistance of the building envelope, excluding windows and doors
- air-tightness of the building envelope as a whole (Blower Door test[5])
- efficiency of boilers (oil, gas and solid fuels), if any
- efficiency of heat pumps, if any
- heat distribution systems, including systems for domestic hot water
- circulation pumps
- ventilation and air conditioning
- lighting (no requirements apply in single-family houses)

5. A Blower Door test measures the leakage of air into the building under a standard pressure difference between inside and outside.

Requirements for "class 2015" and "class 2020" buildings

The table below gives examples of the differences between present Danish minimum requirements (Building Code of 2010) and those which apply to Class 2015 and Class 2020 buildings.

	Mandatory 2010	Class 2015	Class 2020
Maximum energy demand/year (residential) HFS is the building's heated floor space in m^2	52.5 kWh/m^2 + 1650 kWh/ HFS	30 kWh/m^2 + 1000 kWh/ HFS	20 kWh/m^2
Ditto (non-residential)[1]	71.3 kWh/m^2 + 1650 kWh/ HFS	41 kWh/m^2 + 1000 kWh/ HFS	25 kWh/m^2
Max. air leakage/second (test pressure 50 Pa)	1.5 l/m^2	1.0 l/m^2	0.5 l/m^2
Max. design transmission loss[2], single-storey	5 W/m^2	4 W/m^2	3.7 W/m^2
Min. energy gain[3] through windows/glazed walls	-33 kWh/m^2year	-17 kWh/m^2year	0 kWh/m^2year

1. Includes demand for lighting.
2. Average heat loss through 1m^2 of the non-transparent parts of the building envelope at 20˚C inside temperature and -12 ˚C outside.
3. Solar heat gain minus heat loss through 1 m^2 of window (facing south-east) during a standard Danish winter.

Long term rather than short term cost efficiency

It may be tempting to have energy efficiency requirements, which target only the "low hanging fruits" i.e. those energy efficiency measures, which are easily implemented and have a high return on investment.

However, this approach does not minimise long term costs. In order to do that, requirements should mandate not only the low hanging fruits but all efficiency measures, which are cost effective in a long term perspective.

If requirements fail to do that, consumption is locked in at a needlessly high level – the lock-in occurs, because retrofitting is much costlier than getting it right at the time of construction.

Also, the construction industry does not necessarily adopt energy efficiency readily and unassisted, even if it is highly cost effective. Developers and building owners tend to be concerned mostly with up-front construction costs, so regulation is required in order to ensure long term cost efficiency.

This can be achieved through energy efficiency requirements which meet a "least cost" criterion with a suitable timeframe. In other words, all energy efficiency measures which reduce the total costs of constructing and operating a building over a certain number of years should be made mandatory.

Of course, the timeframe for a "least cost" criterion should not be longer than the expected lifetime of the building or building component in question. On the other hand, a much shorter timeframe does not reduce costs – it only makes them temporarily invisible[6].

It may be difficult to assess the value of future savings in energy consumption with a high degree of certainty. However, the long term trend for energy costs has been upward for more than a century and this is expected to continue. Therefore, mandating tried and tested energy efficiency measures would seem to carry a very low investment risk.

Also, as soon as an energy efficiency requirement takes effect, innovation and market forces will work relentlessly to reduce the cost of compliance. The effect of this can be quite significant, and in most cases it makes ambitious energy efficiency requirements pay off more handsomely than expected.

The Danish experience with energy efficiency regulation confirms all of this. Successive revisions of the Danish building code have mandated energy efficiency measures with payback times up to 30 years at current prices. Time and again, this has increased the pace of innovation and brought more efficiency sooner and at a lower cost than predicted.

Danish windows – an example

The Danish market for windows provides a good example of how efficiency requirements may spur innovation.

In 2009, after much discussion, authorities and industry agreed on the performance requirements that would come into effect by 2010, 2015 and 2020.

Performance was defined as the net energy loss (heat loss + solar heat gain) through one m^2 of window (facing south-east) during a standard Danish winter. The limits agreed were max. 33 kWh by 2010, max. 17 kWh by 2015 and max. 0 kWh by 2020.

In other words, by 2020 the sum of heat gains and heat losses through a new window must be positive or zero.

This is a major change compared to existing windows, which have significant net heat loss.

At the time of the agreement some in the industry expressed concern that this would be difficult to achieve. But now, only 3 years later, the most efficient windows on the Danish market exceed the 2020 requirement by a rather impressive margin. The best windows are not only energy neutral; they provide an energy gain of 25 kWh per m^2 of window. Also, they are only marginally more expensive than other windows and this is more than compensated for by the extra energy savings they provide.

6. The IEA recommends a "least cost" criterion with a time frame of 30 years.

Provide builders with a choice between different performance levels

Since 2006 the Danish building code has been providing builders with a choice between 3 different performance levels – a mandatory minimum standard plus two "premium" options, which require higher levels of performance.

At present, the mandatory minimum standard is "Building class 2010" (named after the year of the latest, major revision of the code). Already this standard requires a level of energy performance which is higher than the mandatory level in any other country.

On top of that, the code provides two options, namely "Building class 2015" and "Building Class 2020", which have maximum allowed energy demand approximately 35% and 65% lower than the present mandatory level. As the names suggest, the two options represent future minimum requirements.

This scheme gives credibility to the notion that options with higher up-front costs are better and more future proof. And it has made 10 to 20% of Danish builders – individuals and private companies as well as public institutions – choose one of the "premium" options rather than the minimum standard. Some of these buildings are in special zones, where the local municipality has decided that new construction must already now comply with class 2015 or 2020 requirements.

As a result, the construction industry has a relatively high number of projects where different technologies and strategies for complying with future minimum requirements may be implemented. Again, this invites innovation and provides capacity building for everyone involved, including authorities, craftsmen, architects and engineers, construction companies and manufacturers of building components.

KEY

Key points and recommendations from the Danish case:

- Design energy efficiency requirements for long term rather than short term cost efficiency.
- Maintain a sustained effort to improve energy efficiency standards. Update requirements regularly, e.g. every 5 – 8 years.
- Announce future energy performance requirements well in advance and provide builders with a choice between present minimum standards and "premium" performance levels, which reflect future minimum requirements.
- Engage the building industry and research institutions in the continuous development of the standards through research and demonstration projects which point to the next level.

Implementation of energy efficiency requirements

Practical implementation of energy efficiency requirements may be similar to that applied to more traditional requirements, e.g. fire protection or structural safety. Although the technical content of energy efficiency requirements is different, the same authorities may be in charge, and crucial steps in the practical implementation process may be shared.

However, implementation may require new technical capacity, e.g. for analysis of technical and economical issues with regard to energy efficiency, for energy performance reviews of new buildings and for test and certification of construction components.

The following sections outline how implementation is handled in Denmark – from overall targets set by the Danish government to practical enforcement of specific requirements.

Institutional set-up

In Denmark, parliament has the legislative power, while the executive power lies with the government and with municipalities. In general, government agencies are in charge of the implementation framework, i.e. executive orders, instructions and guidelines.

At government level, implementation of energy efficiency in Danish buildings belongs under the Ministry for Climate, Energy and Building and, more specifically, the Danish Energy Agency, which is in charge of the building code.

Municipal administrations take care of local, practical implementation, and most often they are the point of contact for the general public. For example building permits are granted by the local municipal administration. Also, municipal councils, which are formed through local elections, may decide on certain local adaptations of national regulation. As mentioned above, many municipalities have decided on zones where new construction must comply with class 2015 or 2020 requirements, which are more stringent than the national minimum requirements.

Decision process for Danish energy efficiency requirements

Based on analysis of technical and economical implications, the Danish government proposes overall energy efficiency targets for new buildings. Targets must be agreed to by parliament and it is preferable to have a broad majority so that targets have long term credibility and are not subject to sudden changes following an election. The present targets were agreed by all but five of the 175 members of parliament.

A small group of staff at the Danish Energy Agency translates these targets into specific building code requirements. The agency is responsible for the building code in general. This ensures that energy efficiency and other concerns like indoor climate and safety issues are treated as a whole.

The Energy Agency is assisted by a group of experts from the Danish Building Research Institute, which provide analysis and advice on technical and economical issues with regard to the code. Also, the Danish Technological Institute[7] and a few specialised test and research centers advise on certain technical issues, e.g. performance and test criteria for ventilation systems, boilers, heat pumps or lighting. To some extent, test and research results from other countries are also being used.

When new regulation is under preparation, the most important stakeholders are consulted regularly. Moreover, proposals are always submitted for public enquiry before they are finalised. In particular, the construction industry, equipment makers, academia, NGOs, national government bodies and municipalities are invited to comment.

7. The Danish Technological Institute is a self-owned, not-for-profit institution, which develop, apply and disseminate research-based technical knowledge mainly for the business sector but also, in some cases, for the Danish government and other public institutions.

How do stakeholders learn about the requirements?

Information about the building code is disseminated in several ways. The Danish Energy Agency runs a dedicated website which has the full text plus additional information about recent changes, guidelines, where to ask for further help, public enquiries on new proposals etc. When major changes occur, information on the website is supplemented by press releases, newsletters and workshops. The main target groups for these information activities are architects and engineers from consulting and auditing firms, construction companies, teaching staff from technical schools and universities, as well as staff from municipal authorities dealing with construction permits.

The Danish Building Research Institute issues guidelines on different aspects of the building code, including software for energy performance calculations and examples of typical construction details which comply with the code.

The Danish Knowledge Centre for Energy Savings in Buildings provides building professionals with know-how and motivation to implement energy saving measures. This includes information about regulation in the building code, provided through work-shops and training, publications and software tools available through the center's web-site.

How are requirements enforced?

Building permits are granted by the local municipal authority, and this makes it the main enforcement agent with regard to the building code. In order to obtain a permit, a developer must demonstrate that construction plans comply with the code, including the energy efficiency requirements. Documentation for this must follow specific guidelines. A building permit is required for new construction, including extensions and single family houses.

When construction has been completed, an energy performance review on the site is required. This must be conducted by an independent and certified auditor, who subsequently forwards a report[8] to the municipality. The building is legal only if it meets the energy performance requirements, so deficiencies must be corrected and corrections documented through a new energy performance review.

In addition, the municipal authority must sample at least 5% of new buildings and make sure that they are tested for air-tightness (blower door test). For buildings, which are to be approved according to the 2015 or 2020 requirements, the sample size must be 100%. Many municipalities have decided to apply this to all new buildings.

If it becomes clear that a new building does not comply with regulation, the local municipal authority must request that conditions are legalised. If this has no effect, it can lead to a police report, upon which prosecution authorities will take the matter to court. Provided that the court agrees with the authorities, the penalty is a fine, the size of which depends on the type and extent of non-compliance. Also, the owner of the building must of course make sure that conditions are legalised.

Another important enforcement mechanism, for new construction as well as for retrofits, is applied to construction products rather than to individual buildings. There are test and certification schemes specifically with regard to energy efficiency for several construction components (e.g. windows, boilers, pumps, ventilation systems). Tests and certification are carried out by independent laboratories.

All in all, Danish enforcement is ensured with a limited administrative apparatus both at the state and local level. The reasons for this include:

1. A high level of information about the regulation. This is helped by the fact that requirements have evolved over many years with no radical shifts or change of direction.

2. A general public understanding and positive attitude.

KEY

Key points and recommendations from the Danish case:

- Consider re-use of the existing set-up for implementation. Although the technical content is different, practical implementation of energy efficiency requirements may be quite similar to that applied to more traditional requirements, e.g. on fire protection or structural safety.

- Consider how to get major stakeholders on board. For example, ambitious requirements can create more business for the construction industry. If the industry is made aware of this and also has an opportunity to comment on the design of requirements, implementation may be more successful.

- Consider ways to provide effective but low-cost enforcement. For example, if there is a significant financial penalty for non-compliance, spot checks may replace costlier means of control (e.g. regular inspection of all buildings), because builders already have a strong incentive to comply.

8. A so-called Energy Performance Certificate.

Foto © Kontraframe / Henning Larsen Architects

Financial drivers

Very often energy efficiency in new buildings is highly cost-effective. Never the less, many new buildings are far from optimal with regard to cost efficient energy performance. This locks consumption and operating costs in at a needlessly high level. The lock-in occurs, because retrofitting is much more expensive than getting it right at the time of design and construction.

While regulation may be the most forceful way to avoid this lock-in, financial incentives can also be helpful, in particular when both policy instruments are designed to go hand-in-hand.

Financial incentives may be in the form of subsidies[9] for energy efficiency investments. Or they can target the return on such investments, i.e. the economic value of energy savings. Taxes on energy increase this value, so that more ambitious energy efficiency measures become cost-effective.

Subsidies may be popular with those who benefit from them, but they are a burden on state coffers. Also, many economists see subsidies as an inefficient way of achieving objectives.

Taxes, on the other hand, create revenue for the treasury. Of course, taxes tend to be unpopular, but it may be easier to gain acceptance if tax is on undesirable energy use rather than on labour income. Also, world market prices do not reflect the true, long term costs from pollution and CO_2 emissions, which come with the use of fossil fuels. In this perspective, taxes on fossil fuels may compensate for a "market failure".

In Denmark, subsidies for energy efficiency investments have been used very sparingly and only for limited periods of time. In contrast, taxes on energy have been a prominent and constant feature of Danish energy policy.

Taxes on energy and CO_2

Since 1977, successive Danish governments have been using energy taxes to encourage energy efficiency and as a means of raising revenue. Energy taxation is part of a trend where taxes are put on consumption rather than on income. Over the years, the scope of energy taxation has been widened and rates have gone up. All along, Danish energy tax rates have been among the highest in the world.

Figure 2 shows examples of present energy tax levels in Denmark and three other industrialised countries (US, Japan and Germany). Taxes on electricity are particularly high, reflecting the fact that one extra kWh of electricity often requires 2–3 kWh's of primary energy. The average Danish consumer price per kWh is almost 0.30 EUR, of which 0.17 EUR is taxes.

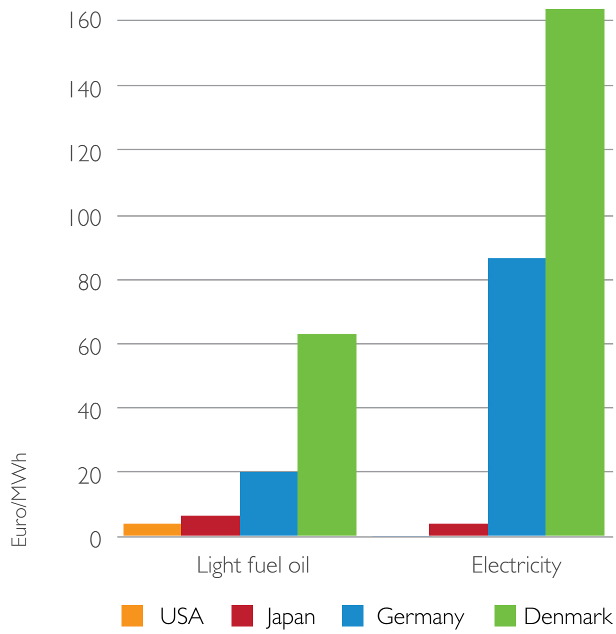


Figure 2. Present taxes (first quarter of 2012) in Euro on fuel for heating and on electricity in United States, Japan, Germany and Denmark. Tax on electricity is not available for the United States. Source: "Energy Prices and Taxes. Quarterly Statistics. First quarter 2012", International Energy Agency 2012.

9. Subsidies may be direct or in the form of tax breaks or subsidised loans.

Tax on energy is a relatively simple instrument, which encourages energy efficiency not only in buildings but in all forms of energy use.

A further advantage is that taxes on electricity and space heating allow for more stringent requirements on energy efficiency in the Danish building code. Requirements must be cost efficient for building owners at current energy prices. So when taxes make these prices increase, the value of energy savings go up, and efficiency requirements can be more ambitious.

Taxes on electricity and oil were introduced in Denmark in 1977, after the first oil crisis. Since then, rates have been increased several times and new taxes on other fossil fuels and biomass as well as on CO_2 have been introduced.

For energy intensive businesses which are subject to international competition, compensatory measures may be required in order to safeguard their competitiveness. In Denmark, these measures include lower tax rates and a scheme that helps such businesses reduce consumption.

KEY

Key points and recommendations from the Danish case:

- Tax electricity and, in cold climates, space heating. This increases the value of energy savings and the incentive for energy efficiency. Taxes may also ease the acceptance of more stringent energy efficiency requirements.
- Consider compensatory measures for businesses which are subject to international competition.

Information and awareness

Regulation and financial incentives are powerful instruments, but their effect depends on how they are implemented. And for implementation to succeed, stakeholders must appreciate and accept what they can or must do.

Therefore, initiatives which increase understanding and acceptance are crucial. Some may be linked directly to the regulation or financial incentive in question. Others may be of a more general nature. In any case, a substantial and sustained effort is required – it is no simple task to change attitudes or to reach the many stakeholders involved.

Danish experience includes many ways of dealing with this challenge:

- Demonstration buildings
- Technical, financial and legal guides
- Free or low cost advice
- Awareness campaigns
- Education and supplementary training for craftsmen, architects and engineers
- Research and development

The following sections outline the Danish activities, set-up and experience.

Demonstration buildings

Actions speak louder than words. This is also the case when it comes to energy performance in buildings. Real-life buildings, which show the way in terms of energy efficiency, can have a profound effect on attitudes and understanding.

Major changes in Danish energy efficiency regulation have been preceded and inspired by real-life buildings which had significantly better energy performance than the then minimum standard. These buildings have demonstrated the technical feasibility and financial benefits of more ambitious minimum performance levels. In this way they have been crucial to acceptance in the building industry and to decisions made by policy makers.

Danish demonstration buildings comprise private, single-family houses (the preferred type of home in Denmark), housing blocks, office buildings and public buildings. Very few of them have been built with demonstration as their only purpose. On the contrary, most were built to function just like any other building of their kind only in a more energy efficient way.

Typically, the investment has been a few percent higher than that required for a similar, ordinary building. However, this has been more than compensated for by the subsequent savings in energy costs. There are also cases where clever design, sourcing and construction practices have provided significantly better energy performance at no extra investment cost.

Almost without exception, the buildings have been paid for by an ordinary investor, e.g. a private individual, a corporation, a social housing association or a municipality. In other words, no subsidies from public funds were involved. In a few cases, manufacturers of energy efficient building components have provided some form of sponsorship for a building. But this has been the exception, not the rule.

All in all, most demonstration buildings have come across as sensible and profitable improvements on mainstream practice, rather than subsidised, futuristic experiments.

Although most Danish demonstration buildings have been funded by ordinary investors, this may not happen in other countries. In that case, it may be helpful if the process gets started through some sort of government intervention – e.g. a decision that certain new developments or individual buildings must achieve a better-than-average level of energy performance.

Foto © Velfac

Annex B provides one such example from Malaysia. It shows how a few demonstration buildings paved the way for new energy efficiency regulation.

Technical, financial and legal guides

Guides in print or on websites can provide information for the construction industry and for other stakeholders at a very low cost. Guides are an indispensable means of communicating recommendations and requirements about energy efficiency.

In Denmark, many organisations, including NGOs and manufacturers of energy efficient building components, have produced such guides. Practically all of them revolve around requirements and options in the building code, and they focus mostly on architectural and technical solutions, which will comply with present or future requirements in the code.

- The Danish Building Research Institute is the central and most authoritative provider of such guides. In particular, they provide the official guide and software for calculating energy performance as required in the Danish building code.
- The Energy Service, an NGO, has guides on energy efficiency and energy savings for the general public and for small and medium sized enterprises in the construction sector. The organization is partly funded by a small share of the revenue from Danish taxes on electricity, which has been earmarked for this purpose.
- A knowledge-centre (Bolius) sponsored by a Danish philanthropic organisation, Realdania, provides information on many issues of interest to house-owners, including energy efficiency.
- The Danish Knowledge Center for Energy Savings in Buildings has a range of guides for professionals in the building industry.
- Danish energy utilities have an obligation to provide a certain amount of energy savings each year. As a part of this effort, they also produce guides for the general public.
- Lastly, manufacturers of building components have guides that explain how to use their products and how to comply with building code requirements.

Free or low cost advice

Personalised advice is of course much more costly than providing information for a broader target audience through printed or web-based guides. However, some of the organisations listed above will provide a limited amount of low-cost or free advice aimed at the construction sector and the general public.

- The Energy Service provides free advice by phone, e-mail or face-to-face at one of their 10 regional offices. Building-owners may also have an advisor visit their building and make an energy performance review, but this will cost a fee. For a single-family house the fee equals the cost of having a skilled craftsman work for 5-6 hours.
- Free advice, but mostly to a lesser extent, is also available from manufacturers of building components, from Bolius and from energy utilities.
- Technical services departments at Danish municipalities will answer specific questions with regard to requirements in the building code.

Awareness campaigns

Since the first oil crisis in the 1970s, Danish governments have launched a number of nation-wide campaigns, which have focused on increasing awareness about energy savings. The latest campaign, in 2011, was aimed specifically at energy savings in homes and included advertising in national Danish television, in newspapers and magazines and on major websites. An earlier campaign, leading up to the COP15 "Climate Summit" in Copenhagen in 2009, had a broader focus on CO_2-emissions in general.

Such campaigns may not achieve much in terms of actual and immediate change. But if they are well designed, they do increase understanding and acceptance, easing the way for more robust policy initiatives.

Education and training

The two leading institutions with regard to education of Danish engineers are The Technical University of Denmark and Aalborg University. Both have departments, which focus specifically on energy efficiency in buildings, and both offer a full range of bachelor's, master and PhD degrees.

Danish architects are educated at Aarhus School of Architecture or at The Royal Danish Academy of Fine Arts. Architecture, in the Danish tradition, is related more to art than to engineering, and students are taught to focus on the user experience, which a building or a built environment will bring about, rather than on complex, technical designs. This approach has lead to some widely admired buildings, and Danish architects frequently win international competitions. Perhaps surprisingly, it has also given rise to a keen interest in sustainable building design, and Danish architects have made several important contributions to the field.

Energy efficiency is not a matter only for architects and engineers. It is equally important that craftsmen in the building sector have the necessary skills, knowledge and motivation. In Denmark, a craftsman's education typically takes 3-4 years. During some periods of this time a future craftsman will work as an apprentice, most often in a private sector company. The rest of the time, which amounts to approximately one year, he or she will attend technical school. There, craftsmen, who are going to work in the construction sector, will learn about best practices with regard to energy efficiency, including current and future requirements in the building code.

Energy efficiency is a moving target. Requirements become more stringent and building design, components and construction methods keep improving. Several Danish organisations provide training that helps building sector professionals keep up with this:

- The Danish Building Research Institute provides high-level training, primarily for engineers and architects.
- The Danish Technological Institute has training courses on a wide range of subjects for craftsmen as well as for architects and engineers
- Training is provided also by technical schools, associations for building sector professionals and by the Energy Service.

R&D

Most publicly funded research on energy efficiency in buildings is carried out at the two leading universities with regard to Danish engineering, the Technical University of Denmark and Aalborg University. The Danish Building Research Institute is a subsidiary of the latter.

The Danish Technological Institute is also an important research institution, funded partly by businesses, which buy its services, and partly by public money.

However, most of the practical, technical solutions, which improve energy performance, are the results of research and development carried out in private sector companies. The list of Danish companies, which have contributed in this field, is quite long and includes makers of building components as well as architects, engineers and construction companies.

Private sector R&D may be partially funded by public money, which is allocated through programs designed to support innovation. For energy efficiency in buildings, the most important program of this kind is the "Energy Development and Demonstration Program". However, the vast majority of private sector R&D projects are conducted without such support. They come about simply because private sector companies are confident about the business case.

KEY

Key points and recommendations from the Danish case:

- Consider how stakeholders may come to understand and accept energy efficiency regulation (and financial incentives). This is crucial to successful implementation.
- Actions speak louder than words. A few real-life buildings, which show the way in terms of energy efficiency, have a profound effect on attitudes and understanding. Make sure that this happens, e.g. by demanding that certain new developments or individual buildings must achieve a better-than-average level of energy performance.
- Make sure that demonstration buildings are sensible improvements on mainstream practice rather than futuristic dreams. Have design and actual energy performance properly documented and publicised, so as to maximise the value of such projects.
- Provide examples and illustrations, which explain implementation of energy efficiency in simple, practical terms. Make such guides available in print, on a website or in any other way which may be well-suited to reach the construction industry and other stakeholders.
- Make sure that guides cover architectural design issues as well as energy systems.
- Consider providing advice also through officers involved in granting building permits or through a dedicated energy efficiency service.
- Implement awareness and training activities which target the building industry and those overseeing compliance. This should be a continuous effort, but most intense around the time of introducing new requirements.
- Make sure that energy efficiency becomes a mandatory topic in the education of architects, engineers and craftsmen.

Key messages

Poor energy performance significantly increases the operating costs of buildings. To a large extent, this can be avoided through simple design measures, which are easily paid for by the saved energy costs. However, many new buildings are designed and built with no regard for this, resulting in a huge waste of energy and money.

The implications are significant. Not only does energy efficiency save energy costs. It may also make costly power failures less likely and reduce the need for huge investments in power plants and transmission lines.

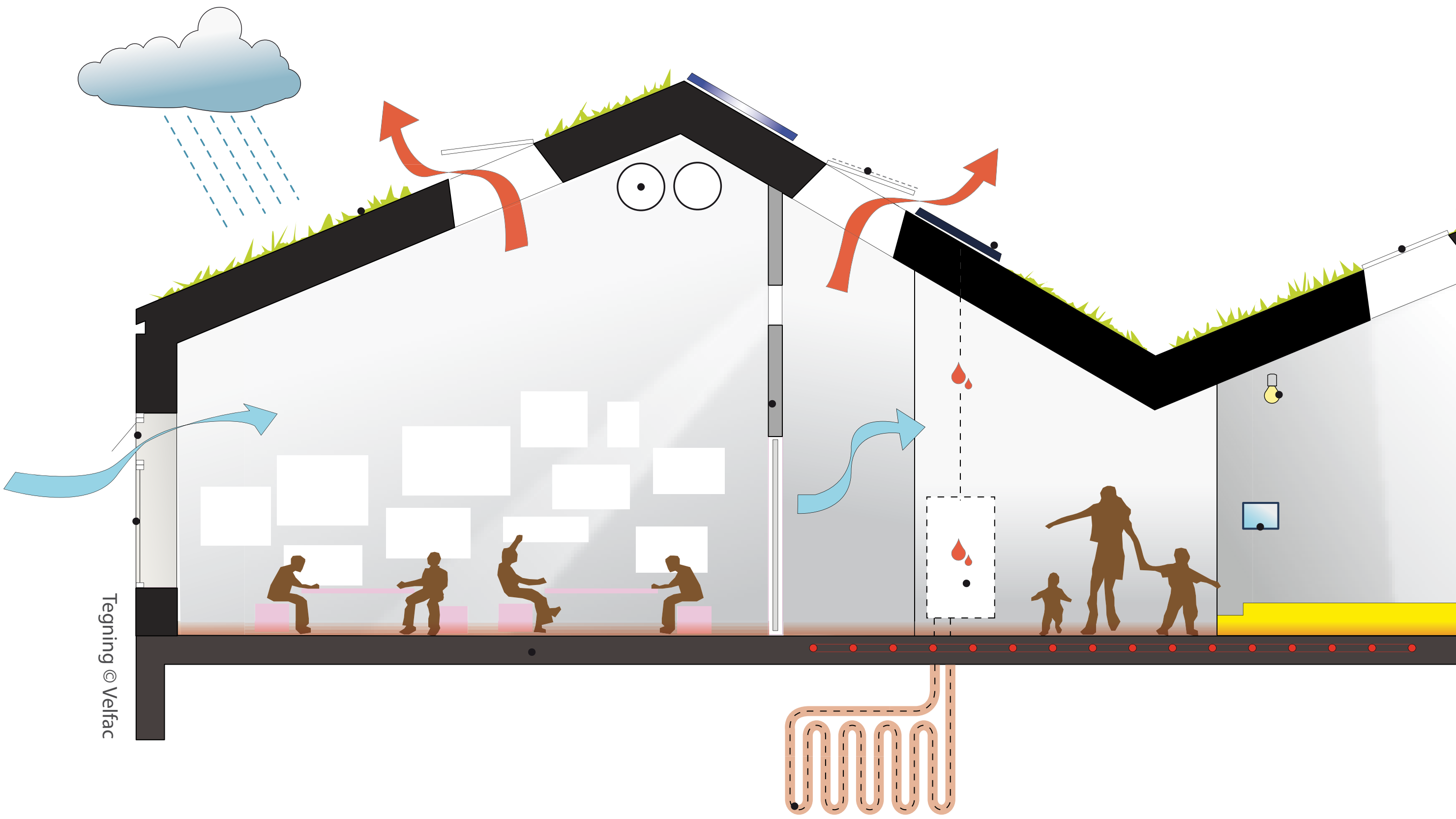
Generally speaking, the cost/benefit ratio of an energy efficiency measure is most attractive in new construction. For example, providing a building which is under construction with energy efficient glazing or air conditioning may be quite a lot cheaper than retrofitting the same components in an existing building. In other words, insufficient energy efficiency in new construction is a missed opportunity, which may lock consumption in at a high level and prove very costly in the long run. This is true everywhere, but it is particularly acute in countries with a rapidly growing building stock.

Many barriers may stand in the way of cost-efficient energy performance in new buildings. Understanding these barriers, and how to deal with them, is the key to a huge economic potential.

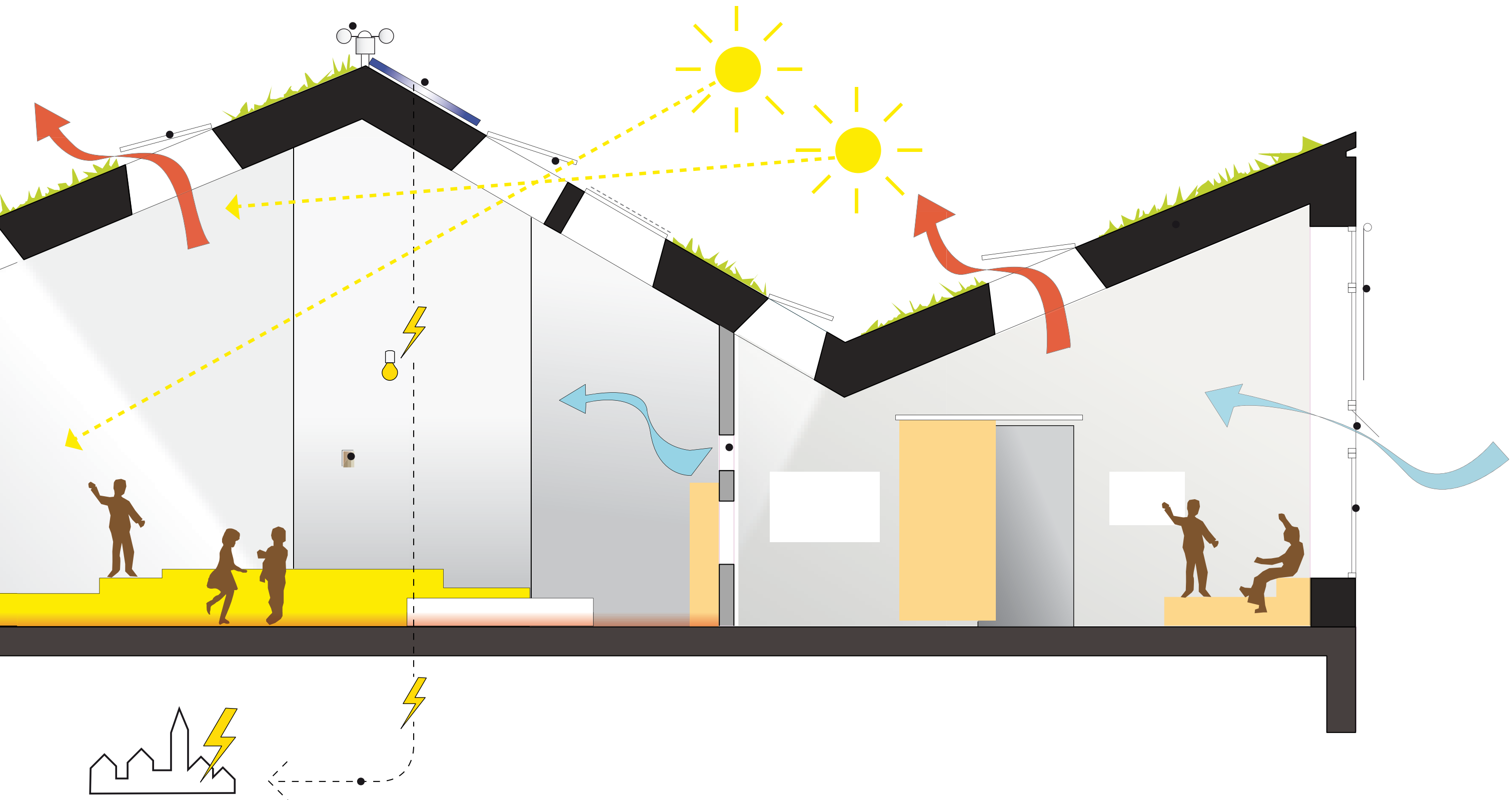
Denmark provides a unique case in this regard. The energy performance of new Danish buildings is widely regarded as the best in the world. And Danish experience on how to turn potential into actual energy savings goes back several decades.

Of course, some aspects of this experience are specifically Danish. But quite a few may be shared across climate zones and different economic environments.

This Policy Toolkit relates how regulation, financial incentives and a commitment to long-term cost-efficiency have reduced energy consumption in new Danish buildings to a fraction of what it was a few decades ago. It also gives examples of building design practice and regulation which have provided significant and highly profitable improvements in energy performance outside Denmark, particularly in tropical and subtropical climates.



Tegning © Velfac



Annex A - Technical sheets

Building geometry and design

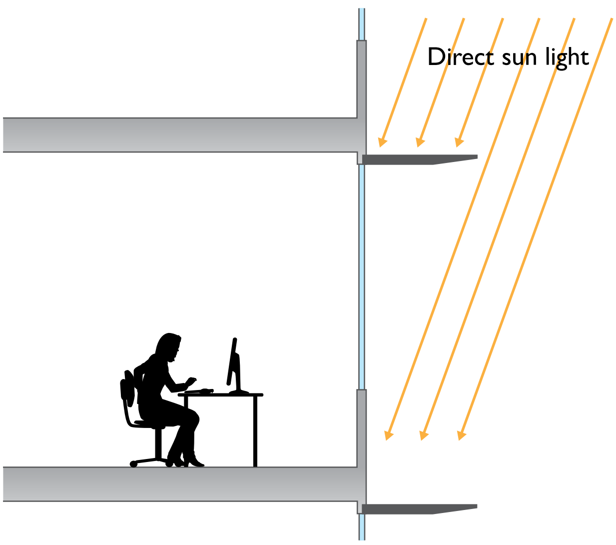
In warm climates near the equator, buildings should preferable be designed to avoid direct sunshine through the windows. This can be achieved using external shading, and by giving priority to windows to the north and the south. Such windows are easy to shade from direct sunshine using an overhang or using the building geometry itself as illustrated below.

Shallow buildings with a wall to wall size not more that 10 – 12 meters are preferable because such buildings allow good daylight availability and good view and comfort from most areas. Secondary rooms such as file rooms, server rooms, toilets, and corridors can be situated in the centre of the building.

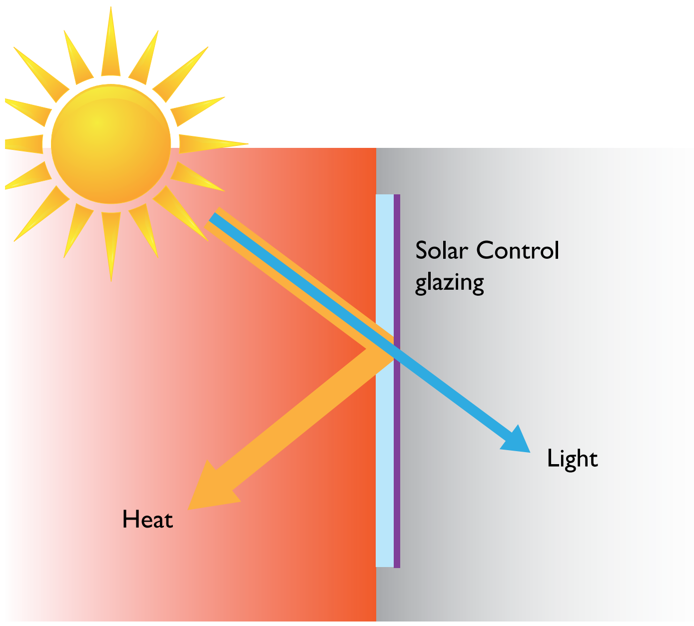
An adequate window area must be provided to allow daylight access and view, however over- glazed facades will lead to overheating, glare problems and increased investments. The optimal window to wall percentage is in the range 40-50%.

The choice of glazing in the facades is important. Double glazing is now becoming available at an affordable price, and they should be chosen. In warm climates with high direct and/or diffuse radiation, solar control glazing (or spectrally selective glazing) should be chosen. This glazing allows visible light in, whereas infrared and ultraviolet radiation, which is heat only, is reflected.

Low emissivity glazing is used a lot in cold climates, because it has a low heat transmission value, which is important when there is a big difference between interior and exterior temperature. However, in hot and humid climates, this temperature difference is relatively small, 5 – 15° C, and low emissivity glazing is not so important, and solar control glazing is the preferred choice.



Windows that face North and South can easily be shaded by a horizontal overhang



In warm climates, glazing should be spectrally reflective, letting in only visible light

Use of daylight

In the Tropics and Subtropics, daylight is typically available through the working day throughout the year, and daylight harvesting to offset electric lighting. In rooms near the building façade, or rooms with rooflight, daylight can cover most of the lighting needs during daytime. In well designed buildings with good daylight availability, daylight can offset at least 50% of the electric lighting load. If the building is designed especially for daylight utilization, almost all electricity consumption for lighting can be saved. This is the case in the Zero Energy Office Building in Malaysia shown below, where the need for electric lighting is reduced by 95% due to the extensive use of daylight as a light source.

However, use of daylight as a light source in tropical buildings is not easy due to two constraints, constraints that up until now daylight is not used as a light source to any significant extent. The challenges are:

1. Allowing daylight into the building also allows a lot of heat into the building, which increases the cooling load and reduces comfort for the people in the building

2. The tropical sky is typically very glary with high levels of diffuse radiation. If the windows are not protected against glare, then this leads to intolerable glare from the sky most of the time

This leads to the typical situation in tropical buildings where the windows are covered by indoor blinds to protect against glare and to reduce heat radiation into the building. However, this also means that electric lighting is on all day, even if daylight is abundantly available outside the building.

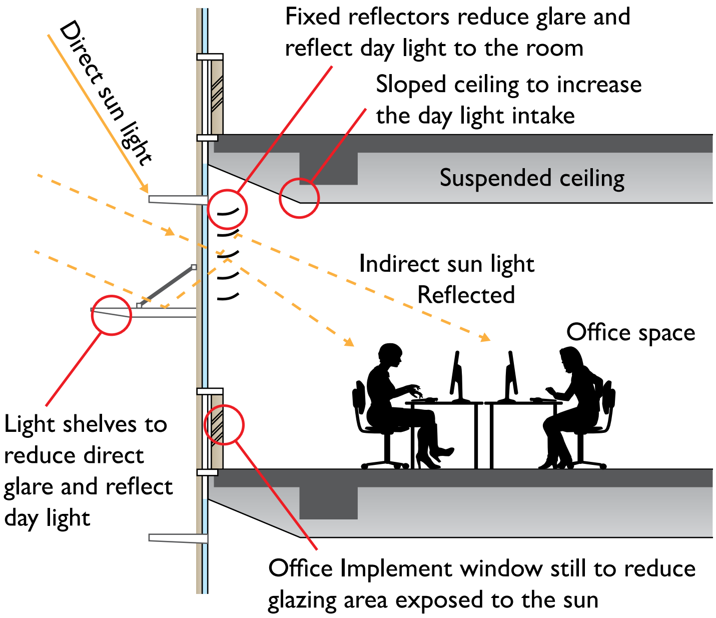


Illustration : IEN Consultants Sdn Bhd

Design features to allow daylight use:

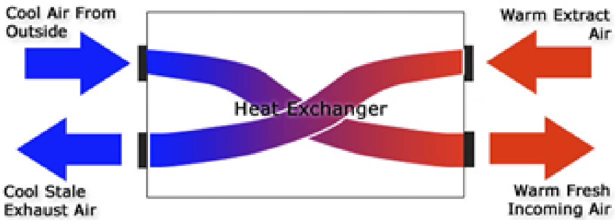
- Use south and north facing windows and use an overhang to block direct sunlight.
- Protect the upper part of the window with fixed blinds so that the user cannot see the sky.
- Use a roller blind to protect the lower part of the window, so the user can control view and glare individually.
- Use a window to wall ratio of 30 – 55%
- Control electric lighting so that lights are only on when daylight is insufficient.

Air tightness

In cold as well as warm climates, a leaky building envelope (façade and roof) will increase the costs to condition the building for heating and/or cooling. Fresh air must be supplied for comfort and health reasons, and this should be provided via controlled admission of outside air through windows and other controlled openings. In non-domestic buildings, a fan driven ventilation system is preferable as this allows the amount of fresh air to be controlled according to occupancy, and because passive preheating or pre-cooling can now be provided using a heat exchanger.

Experience shows that leaky buildings can have an uncontrolled air infiltration rate of 5 – 10 air exchanges per hour, whereas what is needed for optimal health and comfort is typically an air exchange rate of 0.5 – 1.5 air exchanges per hour.

Especially in the tropical hot and humid climate it is important to avoid unwanted air infiltration into the building. This is because the hot and humid air that enters the building prompts a high cooling load not just to cool down the air, but even more important, to dehumidify the air. And dehumidification of humid are that leaks into an airconditioned building leads to large extra costs for cooling, without any benefits to the comfort of the users of the building.



Buildings should be "sealed" and fresh air provided by a controlled ventilation system with heat recuperation.

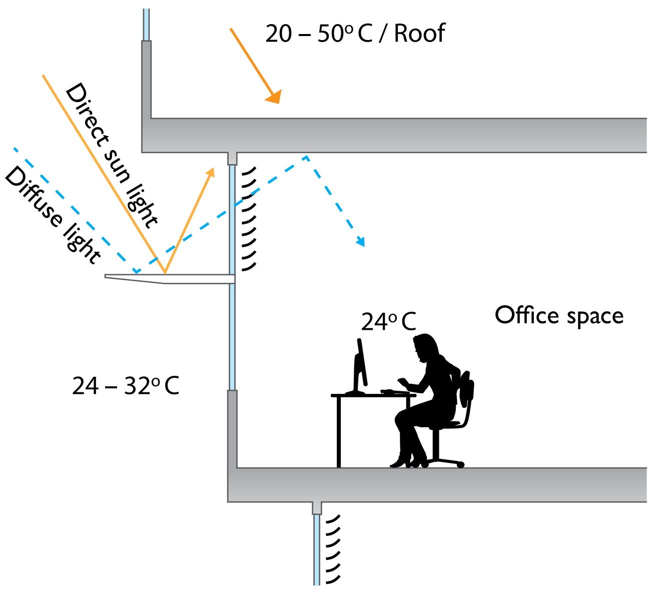
Once the building has a proper ventilation system, then the admission of fresh air can be controlled according to the occupancy level. The level of CO_2 inside the building is an excellent measure of the amount of people inside the building. More people means that the CO_2 level increases and this will then increase the amount of fresh air that is pumped into the building, and visa versa with a low CO_2 level.

A comfortable and healthy indoor climate is achieved by securing good access of fresh air, and by securing that there are no building materials inside the building that contaminate the air. If harmful and smelly building materials are used, then the ventilation rate will have increased significantly with a large increase in the cooling load as a result.

Thermal insulation

Thermal insulation of the building envelope is important to prevent loss of heating or cooling to the outside, depending on the climate. If the indoor temperature and the outdoor temperature are very close, thermal insulation is less important, whereas as in the Danish climate, with a temperature difference during wintertime of 20 – 30° C, thermal insulation is important to prevent heat loss.

In warm climates, the temperature difference is typically less, 0 – 10° C as shown in the section below. At nighttime, the temperature difference will be very small, whereas during daytime it may be 10 – 15° C. However, during daytime, solar radiation will heat up the roof, so that the temperature difference may be up to 20 – 30° C. Therefore, thermal insulation is more important in the roof than in the walls of tropical buildings. Green roofs are beneficial because they reduce the roof temperature and therefore reduce heat load from the roof. However, green roof cannot generally offset the need to insulate the roof.



Section through a daylit building in the tropics with split window design and light shelves, the Zero Energy Office Building in Malaysia.

In cold climates, the roof will typically be colder that the walls due to the cooling radiation effect of the roof facing a cold night sky. Therefore, in cold climates, higher insulation levels are also recommended for roofs also.

In cold climates like the Danish, an insulation level of 20 – 40 cm mineral wool or equivalent of the walls and roofs are recommended. In warm climates, tropical and subtropical, the roof should typically be insulated with at least 100 mm of mineral wool, or equivalent. The walls should be insulated with at least 50 mm of mineral wool or equivalent.

	U-value W/m²K	Equivalent thickness of mineral wool, mm
Walls	0.4 – 0.35	50 – 90
Roof	0.25 –0.35	100 – 150
Windows	2.0 – 3.0	(Douple Glazing)

Glazing in windows should be spectally selective so that only visible light is let in. This reduces heat radiation into the building via the windows by 50%.

Recommended thermal insulation values for a building envelope in the tropical hot and humid part of the world. In hot and dry climates where the outside temperature may exceed 40-45°C during daytime, walls and roof should have an even lower U-value

Cooling

Reduction of the cooling load is a question of addressing the following main design features:

- Reduce the heat load from the outside through windows, walls and roofs and via air infiltration
- Reduce the heat load that is added inside the building from lighting and other equipment
- Improve the efficiency of the cooling system.

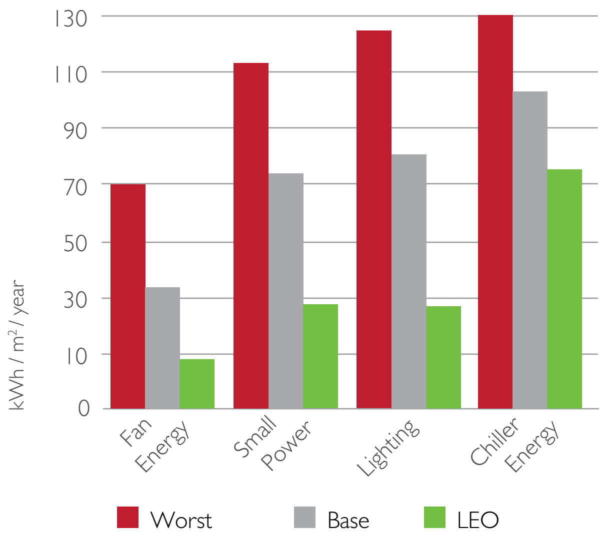
Reduction of the heat load from the outside through the building envelope is very important.

The importance of reduction of the heat load from inside the building is illustrated in the diagram below left. Here the effect of using energy efficient fans for the airconditioning system, energy efficient lighting and energy efficient IT equipment (computers, printers etc) is shown for a typical office building in the tropics (Malaysia). Three cases are shown, a worst case which is not unusual with very inefficient equipment, a typical base case, and the LEO case, which is the actual performance for the Ministry of Energy, Green Technologies and Water "Low Energy Office" in Malaysia. The energy design and follow up of this project was supported by the DANIDA, the Danish International Development Assistance.

Reduced electricity consumption for fans, IT equipment and lighting is very considerable, and in the 4th set of bars, the resulting reduction in electricity consumption for cooling is shown. Reducing electricity consumption inside the building has the added benefit of reducing the cooling load,

Choosing an efficient chiller to provide the cooling that is needed is the next important step. In the diagram the Coefficient of Performance (COP) for various chillers is shown. COP is the amount of cooling provided divided by the amount of electricity consumed, so the higher the better.

The larger the chiller, the higher COP. However the new generation of small individual variable speed split aircon units should be noted. A high COP is achieved with a quite simple installation.



Typical COP values for various chillers

Equipment	Size	Good Practise COP	Best Practise COP
Air cooled, with condenser	< 500 kWr	2.9	3.1
	500 kWr – 1000kWr	3.0	3.2
	≥ 1000 kWr	3.1	3.4
Split Aircon Units, conventional	2 kWr – 10 kWr	2.5	3.0
Variable Speed Split Aircon Unit (new generation split units)	3 kWr – 20 kWr	4.0	5.0
Water cooled, positive displacement (Rotary Screw)	< 500 kWr	4.4	5.0
	500 kWr – 1000 kWr	5.0	5.4
	≥ 1000 kWr	5.7	6.1
Water cooled, centrifugal	< 1060 kWr	5.7	6.3
	≥ 1060 kWr	6.1	7.0

Source : IEN Consultants Sdn Bhd, Malaysia. www.ien.com.my

Lighting

Electricity consumption for lighting can be reduced using energy efficient light sources. Installed lighting load to produce 350 lux can vary from 30 W/m² at worst down to 6 W/m² at best. Furthermore substantial savings can be achieved by controlling the electric light according to occupancy (lights off when the space is not in use) and according to daylight availability.

If the installed lighting load is reduced from 30 W/m² to 10 W/m², electricity consumption is reduced by 75 kWh/m²year, including savings achieved in the cooling load. By comparison, a well designed office building in the tropics (Malaysia) will have a total electricity consumption of 100 kWh/m² per year.

Energy Efficient Lighting Technologies

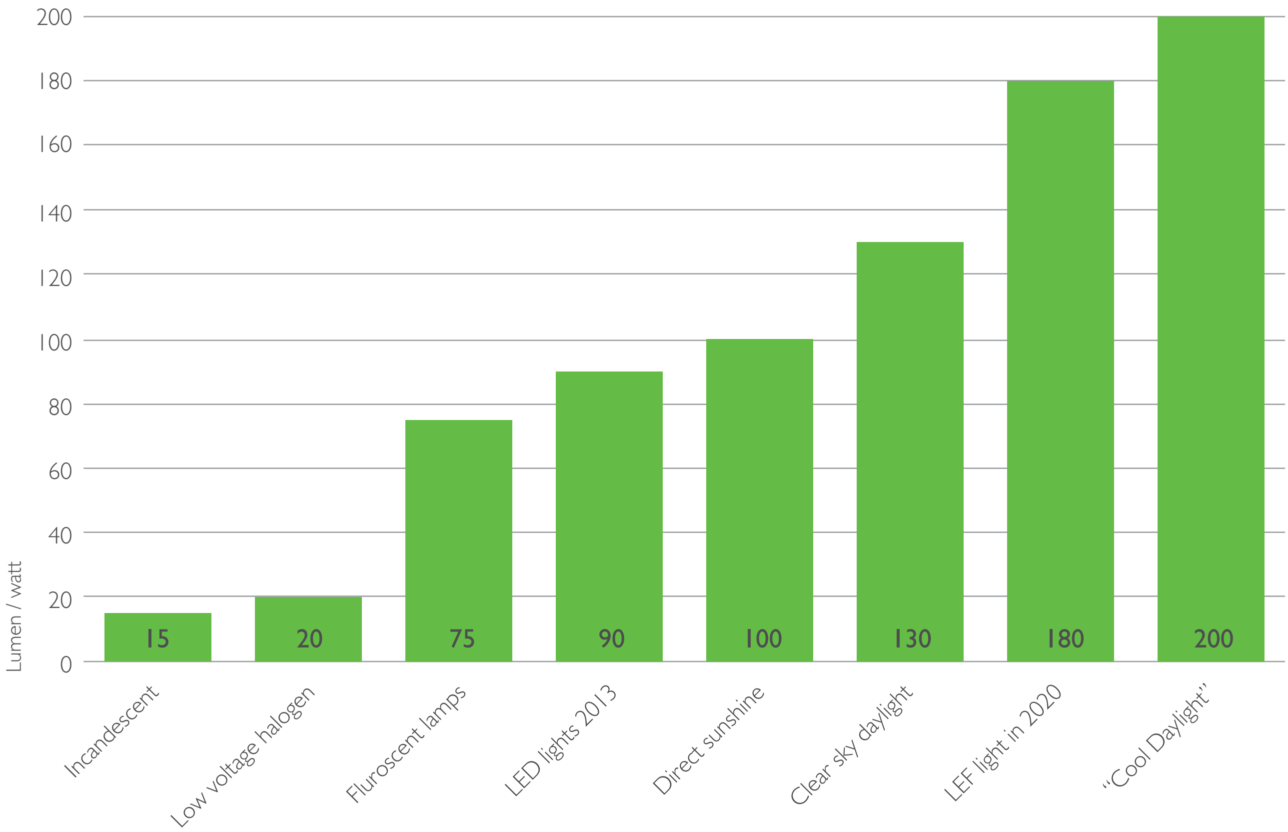
- Use flourescent lighting instead of incandescent lighting or halogen lighting
- Use electronic ballasts or low loss magnetic ballasts for fluorescent lighting
- Control lighting according to occupancy and daylight availability

Using the best lighting fixtures and the best fluorescent tubes, and occupancy sensors and daylight harvesting, lighting load can be reduced by 80 – 90% compared to an old inefficient system !

LED lighting is even more efficient than fluorescent light, more light for less electricity and less heat emission. Furthermore LED lighting promise a much longer lifetime than fluorescent lighting. However, LED lighting is still quite expensive, and quality may still be an issue.

Installed Lighting Load in offices Malaysia to achieve 350 lux	
Bad design	25 –40 W/m²
Typical Design	15 – 25 W/m²
MEGW's LEO building	12 W/m²
PTM's ZEO building	4.8 W/m²

Fluorescent and LED lighting is energy efficient. However, using daylight as a light source is free of charge, and as shown daylight carries even less heat than any electric light source, excluding the future expectations on LED lighting. "Cool Daylight" is daylight which has passed through solar control glazing.



Annex B - Demonstration projects – concrete examples from Malaysia

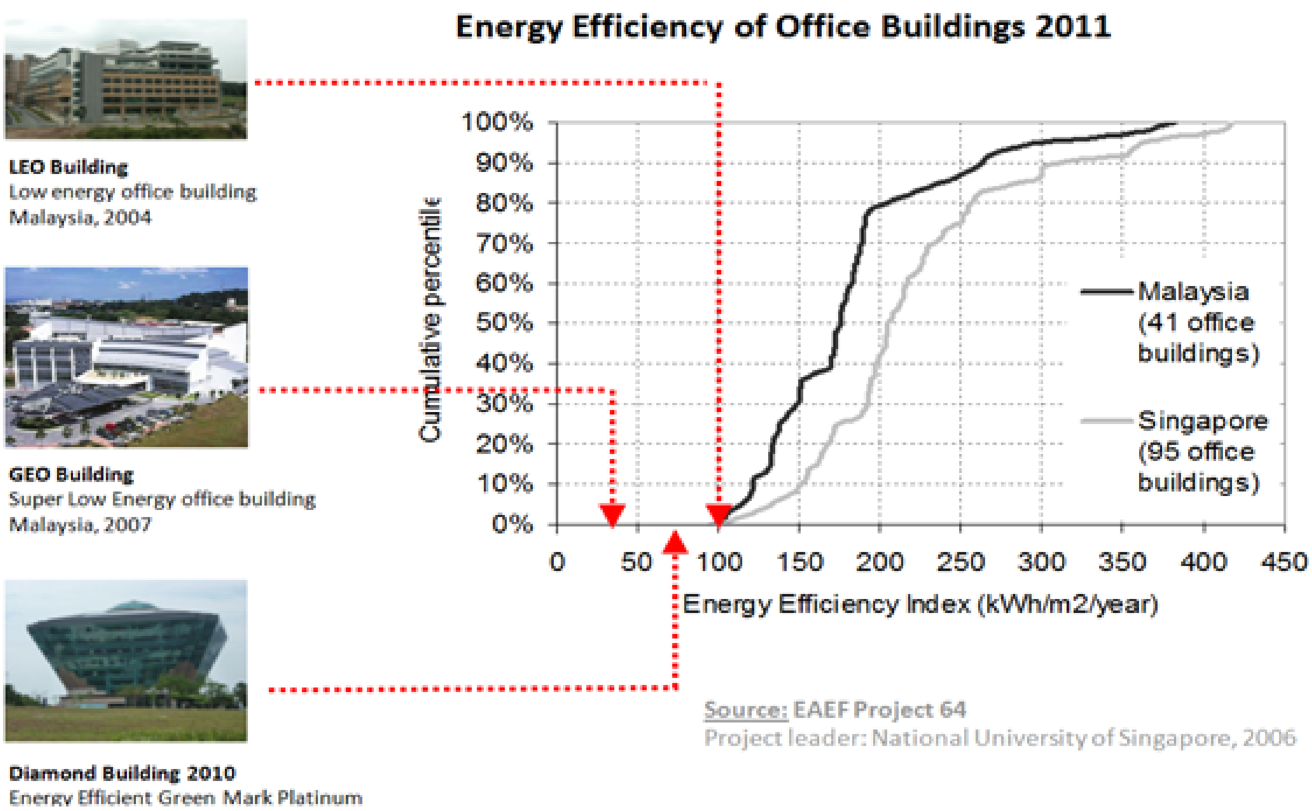
Demonstration projects to show the technical and economic feasibility of designing and building buildings that has a much lower energy consumption has been instrumental by beginning a development where energy efficiency is becoming part of legislation in the Building By-Laws.

In 2001, the Ministry of Energy, Green Technologies and Water decided that their new building in Malaysia should be a showcase for energy efficiency in buildings. This building, the Low Energy Office Building, or LEO Building, has an energy consumption of only 100 kWh/m^2 per year, as compared to traditional buildings with an energy index of 200 – 300 kWh/m^2 per year, as illustrated in the diagram below. The design, implementation and follow up on actual energy performance were supported by DANIDA, the Danish International Development Assistance.

Knowing the actual energy consumption is important, and in 2006 the typical energy index of office buildings in Malaysia and Singapore was documented in a cooperative project supported by the EU Asean Energy Facility.

The LEO building demonstrated that a new office building could be designed and built to reduce energy consumption by 60% compared to a traditional building, with an extra investment of 5% only. Even with the low electricity tariffs in Malaysia, this meant that the extra investments were paid back in only 5 years.

The success of the LEO building led to more energy efficient showcases by the Ministry of Energy, Green Technologies and Water : The Zero Energy Office Building for Greentech Malaysia (35 kWh/m^2 per year) and the Diamond Building (65 kWh/m^2 per year) for the Malaysian Energy Commission. The Zero Energy Office Building is a highly innovative research project, not a demonstration project.



Source: EAEF Project 64
Project leader: National University of Singapore, 2006

The Low Energy Office Building for the Ministry of Energy, Green Technologies and Water in Putrajaya, Malaysia, 2004

Energy Index : 100 kWh/m^2 per year

Received the Asean Energy Award in 2006

The Diamond Building for the Energy Commission in Putrajaya, Malaysia 2010

Energy Index : 65 kWh/m^2 per year

Received the Asean Energy Award in 2012

Design features of the Diamond Building

The diamond building is a natural enhancement of the LEO building design, where a comprehensive integrated design was developed combining active and passive features into a building with a very low energy index. The individual features of the Diamond Building are:

- A self shading facade that eliminates the need for exterior shading. This inverted pyramid facade gives a unique architectural design shaped by energy efficiency, something that was part of the design brief of the client. The building should stand out as a green and energy efficient building.
- Facades (behind the glazing) are insulated with 50 mm mineral wool, and the roof has 100 mm Styrofoam insulation. Part of the roof is covered with greenery to reduce the roof temperature.
- Special care has been taken to secure an airtight building envelope.
- Facade design with light shelves and blinds to cut off glare to improve daylight utilisation in the building. Approximately 50% of the lighting needs are covered by daylight.
- An internal atrium that allows daylight into the centre of the building.
- A 71.4 kWpeak PV system integrated in the roof of the building.
- Very Energy efficient lighting design (T5 tubes with electronic ballasts), controlled according to occupancy and daylight availability
- A low pressure ventilation system with heat recuperation, and high efficiency fans that are controlled according to occupancy measured via the CO_2 content of the indoor air.
- Primary cooling is provided via cooling coils embedded in the exposed concrete ceilings of the building. This allows high temperature cooling and storage of cooling load from nighttime to daytime.
- Only energy efficient office equipment is used in the building.
- The building receives chilled water from the district cooling system in Putrajaya. Therefore energy efficiency for the chiller could not be demonstrated.
- An extensive commissioning and fine tuning period of one year was instrumental in bringing the actual energy consumption even below the predicted energy consumption. The design target was an energy index of 85 kWh/m^2 per year, whereas the actual energy index achieved is around 70 kWh/m^2 per year, with less than 100% occupancy it has to be noted. Subtracting the electricity production of the PV system, the energy index is down to 65 kWh/m^2 per year, a very impressive number compared to normal new office buildings with an energy index of typically around 200 kWh/m^2 per year.
- n addition to the energy efficiency features of the building, then the building has a range of other green building solutions, including rainwater harvesting, recycling of grey waste water, sustainable building materials, and many others. The building has received the highest green building awards in two certification schemes: Green Building Index Platinum (Malaysia) and Gren Mark Platinum (Singapore).

The successful demonstration projects has changed the market perception in Malaysia on energy efficiency in buildings, and the newly introduced Green Building Index certification scheme is benefitting on this program. Energy efficiency is the most important category in this green building certification scheme, and maximum energy points for an office building is scored for a building with an energy index of 90 kWh/m^2 per year or less. This would not have been possible without a series of demonstration projects that proves the feasibility of highly efficient buildings at this level.

Design features of the LEO Building

- Facades are primarily oriented to the North and the South with "Punch Hole Windows" to protect against direct sunshine.
- Facades are insulated with 100 mm aerated concrete blocks, the roof has 100 mm polyurethane foam.
- Energy efficient lighting controlled according to occupancy and daylight availability
- A low pressure ventilation/cooling system with high efficiency fans that are controlled according to the cooling load.
- Users use only energy efficient office equipment.
- The building receives chilled water from the district cooling system in Putrajaya. Therefore energy efficiency for the chiller could not be demonstrated.
- An extensive commissioning and fine tuning period of one year was instrumental in bringing the actual energy consumption down to the predicted energy consumption, 100 kWh/m^2 per year.

Key points on successful energy efficiency demonstration buildings:

- The Government leads the way by walking the talk, by building energy efficient buildings.
- Documentation of technical and economical feasibility is of paramount importance for credibility.
- Demonstration projects must be designed for the local building traditions and the local climate.
- Receive international recognition, such as here with three Asean Energy Efficiency Awards
- Documentation of design, investments and actual performance very important for credibility.
- The demonstration projects provides a platform for capacity building of the building industry
- The projects furthermore promote innovation through developing advanced pilot projects.

Energy Policy Toolkit on

Energy Efficiency in New Buildings

Experiences from Denmark

This is one of a series of energy policy toolkits by the Danish Energy Agency providing specific, technical and concrete information on Danish experiences and measures and results in promoting renewable energy and energy efficiency, targeting practitioners, governmental energy experts and policy makers.

The Danish Energy Agency can also offer to engage in assessing the measures and policies from the Danish case under specific country circumstances through cooperation with countries and in the form of workshops and seminars.

Comments to this policy toolkit as well as queries on the Danish Energy Agency's Global Assistance are most welcome. The idea is to further refine recommendations according to identified needs in growth economies and developing countries.

Comments to this paper as well as queries on the Danish Energy Agency's Global Assistance initiative are most welcome and may be directed to:

Mr. Kristian Havskov Sørensen, Chief Advisor.
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For more information on the Danish Energy Agency's Global Assistance please visit www.ens.dk/en/Global-assistance

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